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Comparison of an Electric Seine and Prepositioned Area Electrofishers for Sampling Stream Fish Communities

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Abstract.—We sampled shallow-water habitats (<1.0 m deep) in a small, spring-fed stream in northeast Oklahoma with an electric seine (ES) and prepositioned area electrofishers (PAEs) to compare the efficacy of the two gear types for characterizing stream fish communities. The ES is commonly used for this purpose, while PAEs are most often employed to relate fish distribution to specific microhabitats. We collected 11 fish species, 8 of which were captured by both gear types. Nonparametric extrapolation methods indicated that the ES and the PAEs estimated species richness similarly, although variation and sampling effort necessary to estimate species richness were higher for the PAEs. We used canonical correspondence analyses to determine if the ES and the PAEs sampled fish communities similarly and to evaluate patterns of species distribution relative to environmental variables. The analyses indicated that the ES and the PAEs sampled fish communities similarly. However, species relationships to environmental variables differed between the two methods, probably due to differences in scale of microhabitat measurements. Our results suggest that both methods can be used to characterize fish communities in small streams. Each method has its advantages: the ES appears to sample more efficiently, but PAEs allow for more thorough evaluation of fish microhabitat use.

Electrofishing methods are often used to sample stream fish communities (Larimore 1961; Lyons 1992; Peterson and Rabeni 1995), and are more effective for characterizing community structure than other sampling methods (Wiley and Tsai 1983; Bozek and Rahel 1991). As interest in the structure of stream fish assemblages has increased, research has focused on estimating sample size and the areal coverage necessary to achieve reliable estimates of species composition and richness. Several types of electrofishing gear have been evaluated, including towed electrofishing units (Lyons 1992), electric seines (Peterson and Rabeni 1995), prepositioned area electrofishers (Bowen and Freeman 1998), and a combination of electrofishing gear types (Paller 1995).

The electric seine (ES) is an efficient electrofishing method that compensates for the disadvantages of other types of electrofishing gear by spreading the electric field over the entire width of the stream, making fish escape difficult (Bayley et al. 1989). Electric seines have been most frequently used to sample both species richness and abundance of stream fish communities (Angermeier and Schlosser 1989; Bayley et al. 1989; Angermeier et al. 1991). However, while an ES is preferred when the goal is to collect community-level information, sampling over large areas of heterogeneous habitat may make it difficult to account for variation in fish distribution associated with microhabitat differences (Bain et al. 1985).

Relating fish distribution to microhabitat variation can be achieved by using prepositioned area electrofishers (PAEs; Dewey 1992; Fisher and Brown 1993; Bowen and Freeman 1998). Prepositioned area electrofishers are most suited for shallow, nonturbid, sparsely vegetated habitats such as riffles, runs, and shallow pools (Dewey 1992). The PAE method can effectively sample different species and age-classes of fish within distinct microhabitats, allowing for precise measurements of habitat variables associated with each PAE (Bain et al. 1985; Bain and Finn 1989). Though it allows for the collection of specific information about habitat use of stream fishes, the PAE method is generally not selected for characterization of fish community structure. However, Bowen and Free-

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man (1998) determined PAEs could generate accurate measurements of species richness or fish abundances in addition to habitat-specific information.

The purpose of this study was to evaluate the efficacy of both the ES and PAE methods for sampling stream fish communities in a small stream in northeastern Oklahoma. Prepositioned area electrofishers sample a relatively small area, and are usually used to relate fish distribution to habitat variables. However, we wanted to estimate the number of PAE samples that would be needed to characterize the fish community. The ES samples almost the entire study area, but may not be as precise in estimating habitat associations because habitat measurements are usually averaged over the entire sample area. Therefore, we wanted to compare the efficiency of the two methods for sampling the fish community and to compare their effectiveness for estimating habitat associations. Specifically, we compared the ability of the two gear types to adequately characterize species composition, size distributions of species, and species richness. We also compared the methods in terms of the relationships between environmental habitat variables and fish distributions.

Methods

Field Sampling

In December 1999, we used the ES and PAE methods to sample fish communities in Brush Creek, Delaware County, Oklahoma. Brush Creek is a small (mean width, 8.9 m), spring-fed stream that extends about 8 km before draining into Lake Eucha. We selected 12 similar shallow-water habitats where depth varied from 0.04 to 0.55 m (mean, 0.28 m), flow varied from 0.00 to 0.02 m^3/s (mean, 0.01 m^3/s), and substrate size varied from 16 mm (large gravel) to 135 mm (large cobble; the mean of all substrate particles was 70 mm, small cobble). Before sampling at each site, two block nets were positioned 20 m apart to eliminate migration of fish during sampling. We used the same Smith-Root 2.5 GPP electrofishing system (AC) with both methods, and voltage was adjusted to achieve approximately 3 A in the water. We randomly chose the gear used at each sampling site, and we sampled six sites with each method.

We systematically positioned PAE grids 2 m apart along transects located 2 m apart throughout the study site. Our PAEs measured 1 m $\times$ 0.75 m, and the number of PAEs used on each transect varied with width of the study site. We set up eight PAEs in the study site at one time and individually energized each PAE for 10 s, with about 10 min allowed between each sample to minimize disturbance. We then rearranged PAEs within the study site and repeated the sampling procedure until all transects had been sampled. The total number of PAEs placed within each site varied from 12 to 18, and our placement of PAEs sampled between 24% and 37% of the area at each site. We identified and enumerated all fish captured from each PAE separately, and measured (mm total length, TL) the first 20 individuals of each species, or as many as were captured if less than 20. After fish samples from all PAEs had been collected, we measured flow and depth in the center of each PAE with a Marsh-McBirney model 2000 portable flowmeter and wading rod. Dominant substrate size in each grid was estimated with a U.S. Geological Survey U.S. SAH-97 gravelometer.

We constructed the ES according to design specifications of Bayley et al. (1989) and Angermeier et al. (1991), making only minor structural modifications. We made two electrode arrays (5 and 10 m) that consisted of 0.5-m lengths of twisted stainless steel cable placed 0.5 m apart across the length of the array. The two arrays could be connected to form a 15-m array. The width of the stream at each sampling location determined the length of array used. Electric seine samples were conducted by making five upstream passes through the entire 20-m block-netted area. For each pass, all fish were identified and counted, and a subsample of up to 20 individuals of each species was measured. Once each site had been sampled, all fish were released. We took three to five measurements (depending on the width of the site) of flow, depth, and substrate size along transects at the location of the upstream and downstream nets after nets had been removed, and at the midpoint of each site. Averages of all measurements were used to characterize flow, depth, and dominant substrate size at each site.

Analyses

Site evaluation.—We used *t*-tests to assess habitat similarity among study sites by comparing mean flow, depth, and substrate size between sites sampled with the ES and sites sampled with PAEs.

Species composition.—Species composition was evaluated for each method in terms of species captured, species-specific catch per unit effort (CPUE), and length-frequency distributions. We used *t*-tests to compare mean CPUE (fish/s) between the ES and PAE methods, using data combined from all sample sites for each species and for all fish captured (SAS Institute 1998). To evaluate whether the two gear types sampled fish size distributions similarly, we used the Kolmogorov–Smirnov two-sample test (Tate and Clelland 1957) to compare length-frequency distributions by species and for all fish measured. Length classes were assigned in 5-mm increments for all species. We used canonical correspondence analyses (CCAs) to compare the effectiveness of the ES and PAE methods for sampling the fish community (ter Braak and Smilauer 1998). We used ''gear type'' as a nominal environmental variable to test the first canonical axis to evaluate sampling differences.

Species richness.—We also wanted to determine if the ES and PAEs estimated species richness similarly. We used nonparametric extrapolation methods, including randomization of sample accumulation order using the statistical software EstimateS (version 5; R. K. Colwell 1997, available at: http://viceroy.eeb.uconn.edu/estimates). Nonparametric extrapolation methods have primarily been applied to estimation of population size and species richness (Colwell and Coddington 1994). Some of the more common species richness estimators have been evaluated in studies of terrestrial communities (Palmer 1990; Colwell and Coddington 1994; Coddington et al. 1996). In comparing estimation methods, Palmer (1990, 1991) found the first-order jackknife (Heltshe and Forrester 1983) to be superior to other methods. Bowen and Freeman (1998) used the first-order jackknife to estimate fish species richness based on PAE samples collected in an Alabama river. However, we chose the Chao 2 estimator of species richness (Chao 1984, 1987), because of its robustness with small numbers of species and small sample sizes (Colwell and Coddington 1994). The Chao 2 estimator,

$$S_2{}^* = S_{obs} + (L^2/2M)$$

(form from Colwell and Coddington 1994), utilizes presence–absence data and estimates species richness according to the total number of observed species (S_{obs}), the number of species that occur in only one sample (singletons, L), and the number of species that occur in exactly two samples (doubletons, M). Note that when no doubletons occur, the estimate is undefined.

We generated species richness estimates at each site, using each pass of the ES and each individual PAE as a sample. Species accumulation curves generated by these analyses allowed us to evaluate the amount of effort needed to accurately estimate species richness within each sampling site for each gear type. Using the final estimate of species richness at each site, we used a *t*-test for populations with unequal variance to compare mean species richness over all six sample sites for each gear type. We then combined either ES passes or PAE samples within each site, and generated species richness estimates for each gear type, with each study site as an independent sample of our target habitat type. This allowed us to evaluate the number of study sites needed to estimate species richness within this type of habitat in our stream.

Responses to environment.—We conducted CCAs for each method separately using the environmental variables of depth, flow, and substrate size to evaluate whether both techniques estimated the same relative importance of environmental gradients and species' positions along the gradients. In all gradient analyses, we used Monte Carlo tests (500 permutations) with an alpha level of 0.05 to determine significance of the canonical axes.

Results

Site Evaluation

After all sampling was completed, *t*-tests showed that mean flow, depth, and substrate size did not differ significantly between sites sampled with the ES and sites sampled with the PAEs ($P > 0.2038$).

Species Composition

We collected 11 fish species in all: 2 species were captured only with the ES, and 1 species was captured only with the PAEs (Table 1). Two of the species captured with only one type of gear, smallmouth bass (ES only) and shadow bass (PAE only), are rarely found in the type of habitat that we sampled, and only one individual of each species was captured. Catch per unit effort of orangethroat darters and slender madtoms was significantly higher for the ES than for the PAEs ($P < 0.03$), whereas there was no significant difference in CPUE between methods for the other six species captured with both types of gear ($P > 0.10$; Table 1). No difference in CPUE between the two methods ($P = 0.10$) was found when all species of fish were combined. Length-frequency distributions of fish captured by both gear types showed no difference for the majority of species (five of eight, $P > 0.05$). However, distributions differed due to the capture of smaller fish by the PAEs for the orangethroat darter and southern redbelly dace, and due to capture of smaller fish by the ES for the central stoneroller. The CCA with gear type as

TABLE 1.—Catch per unit effort (CPUE) and species composition of stream fish captured from Brush Creek, Delaware County, Oklahoma, in December 1999 with prepositioned area electrofishers (PAEs) and an electric seine (ES). Abbreviations of species' names are used in ordination plots (Figure 3). Asterisks (*) denote significance at $P < 0.05$.

Species	Abbreviation	Method	Mean CPUE (fish/s)	
			ES	PAE
Banded sculpin *Cottus carolinae*	BSC	ES, PAE	0.0334	0.0630
Cardinal shiner *Luxilis cardinalis*	CRD	ES, PAE	0.0171	0.0543
Central stoneroller *Campostoma anomalum*	STN	ES, PAE	0.1050	0.1087
Creek chub *Semotilus atromaculatus*	CRK	ES, PAE	0.0016	0.0054
Fantail darter *Etheostoma flabellare*	FTD	ES, PAE	0.0079	0.0207
Orangethroat darter *Etheostoma spectabile*	OTD	ES, PAE	0.0115*	0.0750
Shadow bass *Ambloplites ariommus*	SHB	PAE		
Slender madtom *Noturus exilis*	SMT	ES, PAE	0.0242*	0.0076
Smallmouth bass *Micropterus dolomieu*	SMB	ES		
Southern redbelly dace *Phoxinus erythrogaster*	RBD	ES, PAE	0.0052	0.0457
Stippled darter *Etheostoma punctulatum*	STD	ES		

an environmental variable showed that the first canonical axis was not significant ($P = 0.39$), indicating that the fish community was sampled similarly by both methods.

Species Richness

Species accumulation curves for each gear type at each site showed variability in species richness among sites for both; however, there was greater divergence between species richness estimates and the number of species observed for PAE samples than ES samples (Figure 1), indicating that the ES was more efficient than the PAEs at collecting all species within a study site. Additionally, estimated species richness was reached using a lower number of samples with the ES than with PAEs. Two to three passes of the ES resulted in accurate estimates of species richness. A minimum of 10 PAEs were generally needed to estimate species richness, and for one site, an asymptote was never reached.With species richness estimated from the endpoints of species accumulation curves, mean species richness estimates were similar between the two methods. However, variance associated with the ES estimate was much lower than that of the PAEs (0.58 for the ES and 13.04 for the PAEs). We also pooled all ES passes by site and all PAE samples by site to estimate species richness for our target habitat type over the larger stream area (about 8 km). Using each study site as an independent sample, the species richness was estimated to be around 11 species by both the ES and the PAEs (Figure 2). The species accumulation curves also indicate that species richness could have been estimated from fewer sample sites (3–4) than used in this study.

Responses to Environment

Ordinations of species scores with depth, flow, and substrate size showed differences in distributions of fish species relative to environmental gradients (Figure 3). All axes were significant in both analyses ($P < 0.004$), but the first two axes in both ordinations explained the majority of variation in species–environment relationships (84.8% for ES samples and 94.1% for PAE samples). In each case, the first two axes were related to flow and depth; however, the relative influence of the two variables in determining species distribution differed between the ES and PAEs. For the ES, CCA determined the primary axis was related to depth and the second axis was related to flow, while the reverse was found for CCA of the PAEs.

Discussion

The two methods estimated species richness similarly at specific shallow-water sites. However, the ES appeared to sample each site more efficiently, and species richness estimates from ES samples were less variable than estimates from PAE samples. We found two to three passes of the ES to be adequate sampling effort to estimate species richness at each site. Previous studies have yielded similar results: two passes of the electric seine through a blocked area effectively sampled the number of fish species, number of individuals, and biomass, with little information being added in subsequent passes (Schlosser 1982; Angermeier et al. 1991).

When considering the PAE method for estimating species richness, the amount of effort necessary for accurate estimates, as well as the variability associated with the estimates, may be cause

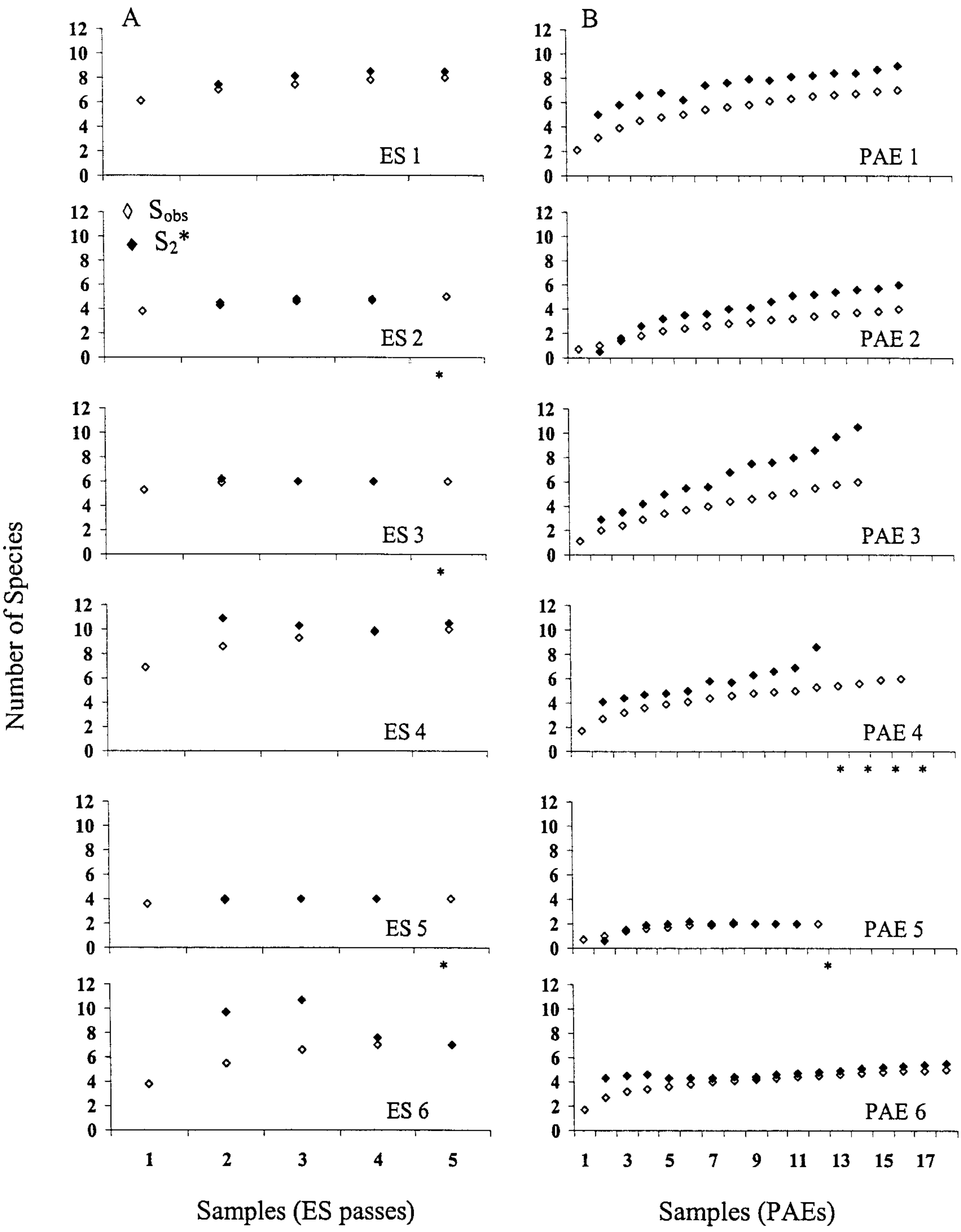

FIGURE 1.—Number of species observed (S_{obs}, open diamonds) and Chao 2 species richness estimates (S_2*, closed diamonds) by study site for **(A)** the electric seine (ES) and **(B)** prepositioned area electrofishers (PAEs). Each point is the mean of 100 randomizations of sample accumulation order. Asterisks denote an undefined estimate due to the absence of doubletons (species occurring in only two samples).

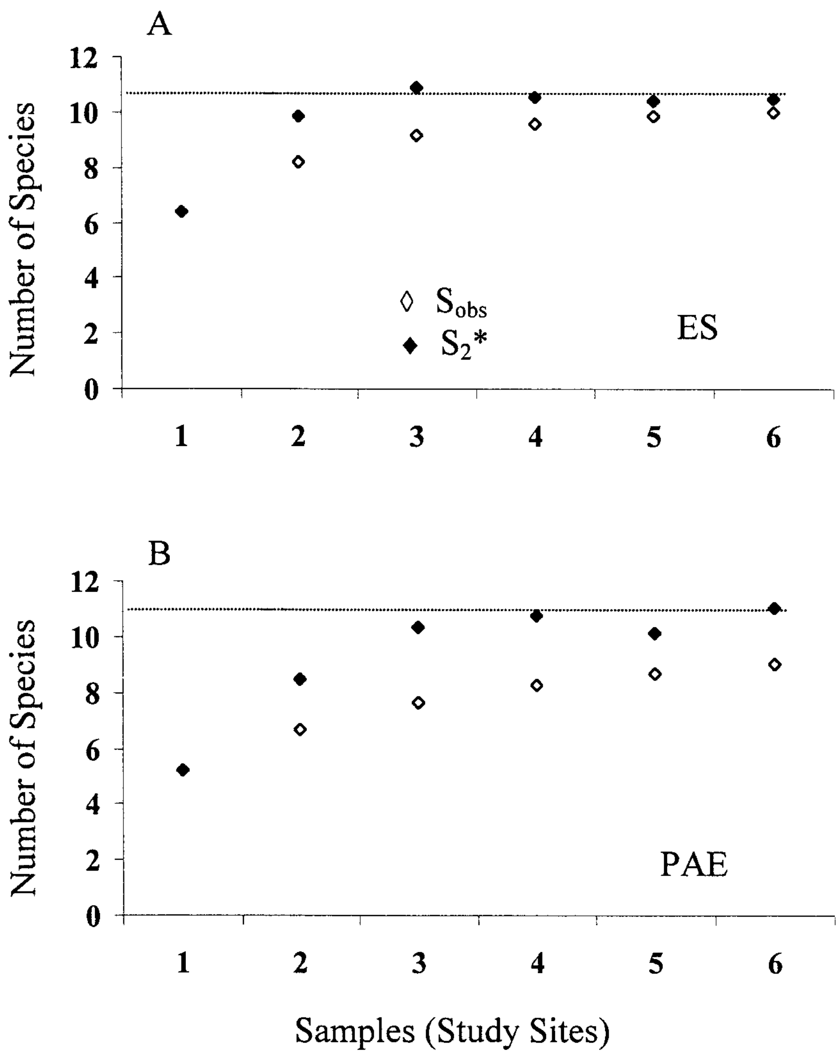

FIGURE 2.—Number of species observed (S_{obs}, open diamonds) and Chao 2 species richness estimates (S_2*, closed diamonds) for **(A)** electric seine (ES) and **(B)** prepositioned area electrofishers (PAEs). Each point is the mean of 100 randomizations of sample accumulation order. Electric seine passes and individual PAEs were pooled by site. Horizontal dashed lines represent the final estimated species richness.

for concern. In this study, 24–37% areal coverage with PAEs did not result in convergence of estimated and observed species richness, indicating that considerable sampling effort (>40% areal coverage) at a site may be necessary to adequately characterize the fish community. Estimated species richness based on PAE samples did not converge with the observed species richness after 15 samples at most sites, and the site for which estimates did converge had a relatively low number of species. Bowen and Freeman (1998), working in a larger river and with larger PAEs, recommended a minimum of 70 PAE samples in each area to estimate species richness and to evaluate the relationship between sampling effort and species richness. When samples within a site were combined, species accumulation curves showed that species richness could have been estimated using only three sampling sites. Considering the higher variability and effort associated with the PAE method, ES sampling would be preferable for obtaining more reliable estimates of species richness with less effort.

Despite the short sampling period for each PAE (10 s), CPUE was similar to that of the ES for most species. Sampling efficiency of the ES has

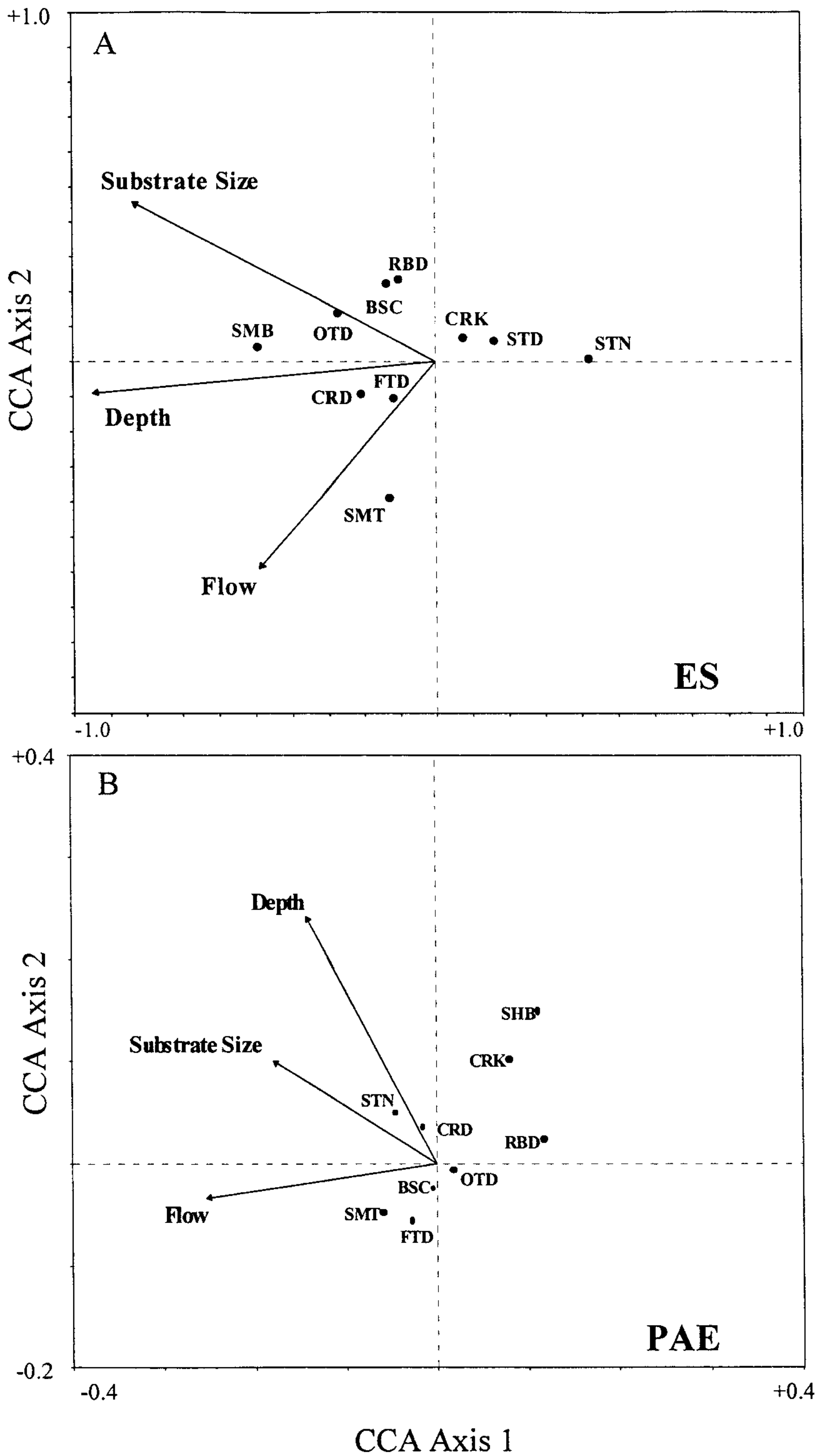

FIGURE 3.—Canonical correspondence analysis (CCA) biplots representing species scores and environmental variables for fish communities sampled from Brush Creek, Oklahoma for **(A)** electric seine and **(B)** prepositioned area electrofishers. Please note that ordinations are not on the same scale. Refer to Table 1 for abbreviations of species' names.

been shown to surpass that of backpack and boat shocking (Bayley and Dowling 1990), and in this study, the catch rate of the ES was roughly equal to that of the PAEs for six species. The ES, like other electrofishing gear, is more effective for sampling certain fish species due to physiology, morphology, and habitat use characteristics (Larimore 1961). Schlosser (1982, 1985) reported the ES to be less effective in sampling benthic species such as darters (Percidae) and catfishes (Ictaluridae). However, if such a bias occurred in this study, the two methods apparently underestimated benthic species in a similar way. The two species captured at a higher rate with the ES were benthic, and there was no difference in CPUE between methods for the other two darter species, the fantail darter and the stippled darter, or for banded sculpin.

Length distributions of captured fish were generally similar, and any differences we found did not reflect a clear pattern of bias by either gear type. Evidence of a bias toward larger fish by the ES (two of eight species) has also been demonstrated in previous gear evaluations (Schlosser 1982, 1985). However, the ES captured smaller individuals of central stoneroller than the PAEs, making any patterns of bias difficult to interpret. Additionally, any bias toward larger fish with the ES sampling may be associated with difficulty in detecting and netting smaller fish over the larger area covered by the electric seine, or may reflect a size bias by netters.

When the specific microhabitat variables of depth, flow, and substrate size were introduced, subtle differences between the two methods became more apparent. Although both analyses reflected the importance of depth and flow to distribution of fish species, the relative influence of these variables was slightly different depending on which gear type was used. We measured each variable within each PAE unit, but averaged transect measurements for the ES, resulting in one value for each variable per site. Habitats within and among sites were fairly homogeneous, so any spatial differences in habitat variables would probably be more readily detected with individual measurements of PAEs. Comparison of the two ordinations indicates that the habitat sampling protocols did not lead to similar conclusions about environmental gradients. For instance, the PAE ordination reflects a logical distribution of species along the gradient of depth. Species usually associated with deeper water, such as shadow bass and creek chub, and shallow-water species, such as slender madtom and fantail darter, were located at opposite ends of the gradient. Although species appear more spread out in the ES ordination, distribution of species along gradients of depth and flow do not conform well with our observations of fish distribution in the field. The ES ordination shows smallmouth bass and orangethroat darter at one end of the depth gradient and stippled darter and central stoneroller at the other end, a pattern that does not reflect actual fish distributions. The PAE ordination appears to more accurately reflect species distribution within and among sites, and to more accurately relate species distribution relative to environmental variables.

We did not formally record the time it took to set up and sample each site because it was not one of our goals. However, due to procedures to minimize disturbance, it took longer to sample PAE sites than ES sites. The time necessary to prepare a sample site was essentially equal for each gear type, and consisted of setting up block nets, electrofishing gear, and fish processing equipment. However, it was necessary to for us to delay sampling by about 20 min after placing the PAEs in the stream, to help minimize the disturbance associated with setting up the grids. Additionally, we waited 10 min between PAE samples because of the disturbance caused while sampling each grid. Electric seine sites took much less time to sample. Excluding the time required to set up and take down block nets, it took our 5-person crew approximately 2 h (25 min of actual electrofishing effort) to completely sample each ES site, while it took approximately 3 h (150 s of actual electrofishing effort) to complete sampling at each PAE site.

Specific research objectives will determine what sampling method to use. Each method has advantages: the ES samples more efficiently, but the PAEs allow for more precise evaluation of fish microhabitat use. Based on our results, we recommend using an ES to accurately and efficiently sample stream fish communities in shallow-water habitats. The amount of time necessary to effectively sample with an ES is less than that of PAEs, and species richness estimates based on 2–3 ES passes were less variable than those based on 10–20 PAE samples. However, specific associations between fish species and microhabitats appear to be best evaluated with the PAE method. Studies with this as a primary goal could use PAEs to simultaneously collect information about fish communities and fish microhabitat usage within the constraints of higher effort and variability.

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